Hydrogen Commercialization: Transportation Fuel for the 21st Century

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Objectives

- Relocate and reassemble the Clean Air Now Project and the Schatz Energy Research Center Project (SERC).
- Produce, compress, store, and dispense hydrogen using grid, solar, and wind electricity and determine cost.
- Move fuel cell vehicles to SunLine from the City of Palm Desert for continued testing.
- Produce hydrogen from a natural gas autothermal reformer.

Approach

- Hire a construction manager to implement the detailed construction plans developed in the earlier phase of the project and adapt them to the SunLine site.
- Prepare the site.
- Construct the following:
- SERC Hydrogen Production Building
- The Palm Desert Vehicle Building
- The Zweig Community and Outreach Building (contribution by SunLine Transit Agency)
- Pad and distribution system for the Solar Flat Plate Arrays
- Pad and distribution system for the Solar Photovoltaic Tracking Arrays
- Pad and utilities for the Stuart Energy electrolyzer
- Pad for the 4,000 psi ground storage tanks
- Pad for the 3,130 psi hydrogen tube trailer
- Pad, utilities and wall for small vehicle refueling area
- Hydrogen underground distribution system
- Pad for hydrogen dispenser at the SunLine public fueling island

Accomplishments

- Installed the following:
  - 0.1-kg Teledyne Energy Systems electrolyzer
  - PDC hydrogen compressor and fueling area for small vehicles
  - 3-kg Stuart Energy electrolyzer

  - 218 Solar Flat Plate Arrays
  - 144 Solar Photovoltaic Tracking Arrays
  - 4,000 psi ground storage tanks
  - 3,130 psi hydrogen tube trailer
  - Dispensing system for small vehicles
  - Dispensing system for buses and automobiles
  - Hydrogen Burner Technologies natural gas partial oxidation reformer
  - 5000 psi ground storage
  - 5000 psi compressors
  - 5000 psi dispenser
  - Controls and valving
- Tested three fuel cell golf carts.
- Tested one street legal neighborhood electric vehicle.
- Tested one EXCELLSiS (formerly-now Ballard) 40-foot fuel cell bus for 13 months.
- Tested one 30-foot ISE Research, Thor Industries, El Dorado, UTC Fuel Cells fuel cell bus for 6 months in fixed route transit service.
- Tested two older model L-10 Cummins internal combustion engine (ICE) buses operating on blended hydrogen and compressed natural gas (CNG) buses.
- Upgraded and modified two new Cummins-Westport 5.9 l B+ internal combustion engines to operate on blended hydrogen and CNG (HCNG).
- Developed the first hydrogen technician training manual, "Hydrogen Fuel Cell Engines and Related Technologies," which is posted on the National Renewable Energy Laboratory's (NREL's) website, and from October 2002 to August 14, 2003, there were 508,321 "hits".
- Demonstrated the production of hydrogen using the Stuart Energy P-3 electrolyzer to support the operation of the XCELLSiS fuel cell (FC) bus and the ThunderPower hybrid electric FC bus (see Figure 1).
- Demonstrated the production of hydrogen from solar energy using the Teledyne Energy Systems Altus 20 electrolyzer (see Figure 2).

Stuart P3 Hydrogen Production

Year	Scf H_2	KWh
2000	833,500	108,100
2001	1,754,737	209,524
2002	832,536	107,933

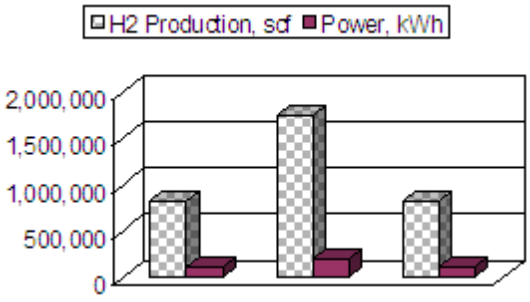

Figure 1. Hydrogen Production Data for the Stuart Energy Electrolyzer

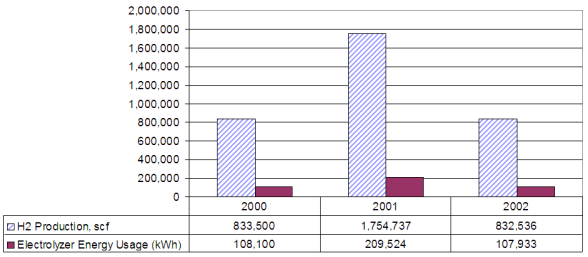

Figure 2. Hydrogen Production Data for the Teledyne Electrolyzer

- Demonstrated the production of hydrogen from solar energy using the Teledyne electrolyzer (see Figure 3).
- Demonstrated the production of hydrogen from the Hydrogen Burner Technology (HbT) natural gas reformer.

Future Directions

- Collect data on the operation of two blended HCNG ICE buses in fixed route service and two Cummins Engine CNG 5.9 l B+ buses in fixed route service, and compare the results.
- In cooperation with Alameda County (AC) Transit, who is purchasing 3 Van Hool 40-foot fuel cell hybrid electric buses, purchase through a Federal Transit Administration (FTA) grant a Van Hool 40-foot fuel cell hybrid electric bus for fixed route service for SunLine Transit Agency.
- Purchase, using SunLine's replacement bus program, a 40-foot New Flyer hydrogen ICE bus for fixed route service.
- Investigate the emissions reduction effects of adding an oxidation catalyst to the ICE HCNG and CNG buses in testing.
- Install and operate a HyRadix natural gas auto-thermal reformer.
- Collect data and investigate the parameters affecting the production of hydrogen from the natural gas reformer.

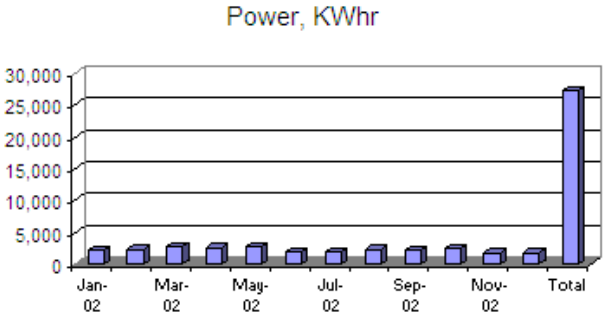

Figure 3. Siemens Solar Panels and Eco-Energies Photovoltaic Tracking Arrays

Period	Energy (kWh)
Jan-02	2,166
Feb-02	2,349
Mar-02	2,757
Apr-02	2,612
May-02	2,774
Jun-02	1,961
Jul-02	1,962
Aug-02	2,330
Sep-02	2,275
Oct-02	2,502
Nov-02	1,746
Dec-02	1,791
Total	**27,225**

Introduction

The President's call to reverse America's growing dependence on foreign oil harkens to the decision SunLine Transit Agency's board of directors made in 1994. That was the year SunLine accomplished the unthinkable by becoming the first transit agency in the world to park all of its diesel buses and switch overnight to a fleet powered 100% by clean-burning compressed natural gas (CNG). That was only the beginning.

Since 1999, SunLine Transit Agency has worked with the U.S. Department of Energy (DOE), U.S. Department of Defense (DOD), and the U.S. Department of Transportation (DOT) to develop and test hydrogen infrastructure, fuel cell buses, a heavy-duty fuel cell truck, a fuel cell neighborhood electric vehicle, fuel cell golf carts and internal combustion engine buses operating on a mixture of hydrogen and compressed natural gas (CNG).

SunLine has cultivated a rich history of testing and demonstrating equipment for leading industry

manufacturers in a pre-commercial environment. Visitors to SunLine's "Clean Fuels Mall" from around the world have included government delegations and agencies, international journalists and media, industry leaders and experts and environmental and educational groups.

This is the final report of a three-year success story, which began with the DOE's decision to establish a hydrogen infrastructure in Southern California at SunLine Transit Agency in Thousand Palms, California. SunLine was tasked with taking two then-current DOE projects and moving them to SunLine to create an infrastructure that produced, compressed, stored and dispensed hydrogen to fuel cell vehicles using grid, solar and wind power.

The investment made by the DOE has yielded significant benefits. Not only was the project constructed as scheduled, but it has surpassed the original goals under SunLine's Best Test Center for Alternate Energy Technologies to become part of SunLine's daily operations and maintenance activities. In other words - our "rolling laboratory" has taken the technology out of the science lab and into the real world.

Approach

The basic approach to the development of the hydrogen infrastructure and the testing of fuel cell vehicles was to treat all of the equipment as if it were commercialized. With this philosophy, all of the problems and issues would be brought forward in terms of operability, maintainability, supportability, reliability, and durability. This type of field testing is valuable to manufacturers and developers because it gives them the areas that need solutions before the product is declared commercialized. It educates the early adopters of technology in the requirements to employ the technology in service. The downside is that early adopters are placed on the "bleeding edge" of cash flow unless the new expensive technology is subsidized by government or private investment.

Results

One of the project's significant objectives was to educate the public on the safety and reliability of fuel cell vehicles. By demonstrating fuel cell bus service using compressed hydrogen in a normal transit operation, officials and riders alike got to experience for themselves the pollution-free transportation technology of the future. Another objective was to show the potential to other transit operators for using a liquid fuel reformed to hydrogen in fuel cell buses.

To further enhance the public education component of the project, SunLine developed several additional strategies. Thirteen two-minute "Energy Matters" videos were distributed to PBS stations in major California media markets. The videos covered such topics as alternative fuels, electricity and the grid, fuel cells, micro-turbines, and new car technologies. The videos were also made available to teachers and administrators for classroom use.

SunLine worked with College of the Desert and other partners to develop the first training manual for hydrogen fuel cells and related technologies. The curriculum, funded in part by the Federal Transit Administration and the Department of Defense, is set to be delivered to students at College of the Desert and other community colleges throughout the state through the California Community Colleges' EdNet initiative.

The Hydrogen Fuel Cell Engines and Related Technologies training manual has also been posted on the NREL website. From its introduction in October 2002 to August 14, 2003, the manual received 508,321 hits. According to NREL, this is the largest number of hits they have ever recorded in that short of a time span. From April 28, 2000, to the current date, over 6,000 visitors from 31 countries have visited SunLine Transit Agency to see and hear the story of the development of the Clean Fuels Mall.

Conclusions

Other than cost, SunLine's track record of experience has identified several challenges to hydrogen commercialization:

- The need to improve fuel cell reliability
- The need to engage the insurance industry in overcoming liability issues
- The establishment of reasonable codes and standards
- The implementation of comprehensive hydrogen education and outreach programs to elevate public awareness to mainstream levels

SunLine has effectively demonstrated the need for a path of continuous improvement. Investments in fuel cell technology should be made on a measured basis of how they contribute to the global body of knowledge. While it is important to test and demonstrate the technology, it is also important to invest wisely. Finite resources should be devoted to those organizations and programs that have demonstrated a passion to make things work, the policies and political will to further hydrogen and fuel cell development and the capability to perform technology transfer to future organizations.

Selective investment is a must.

References

1. Final Report to the Department of Energy, February 2003, "Hydrogen Commercialization: Transportation Fuel for the 21st Century", Contract Number: DE FC36-96GO10139